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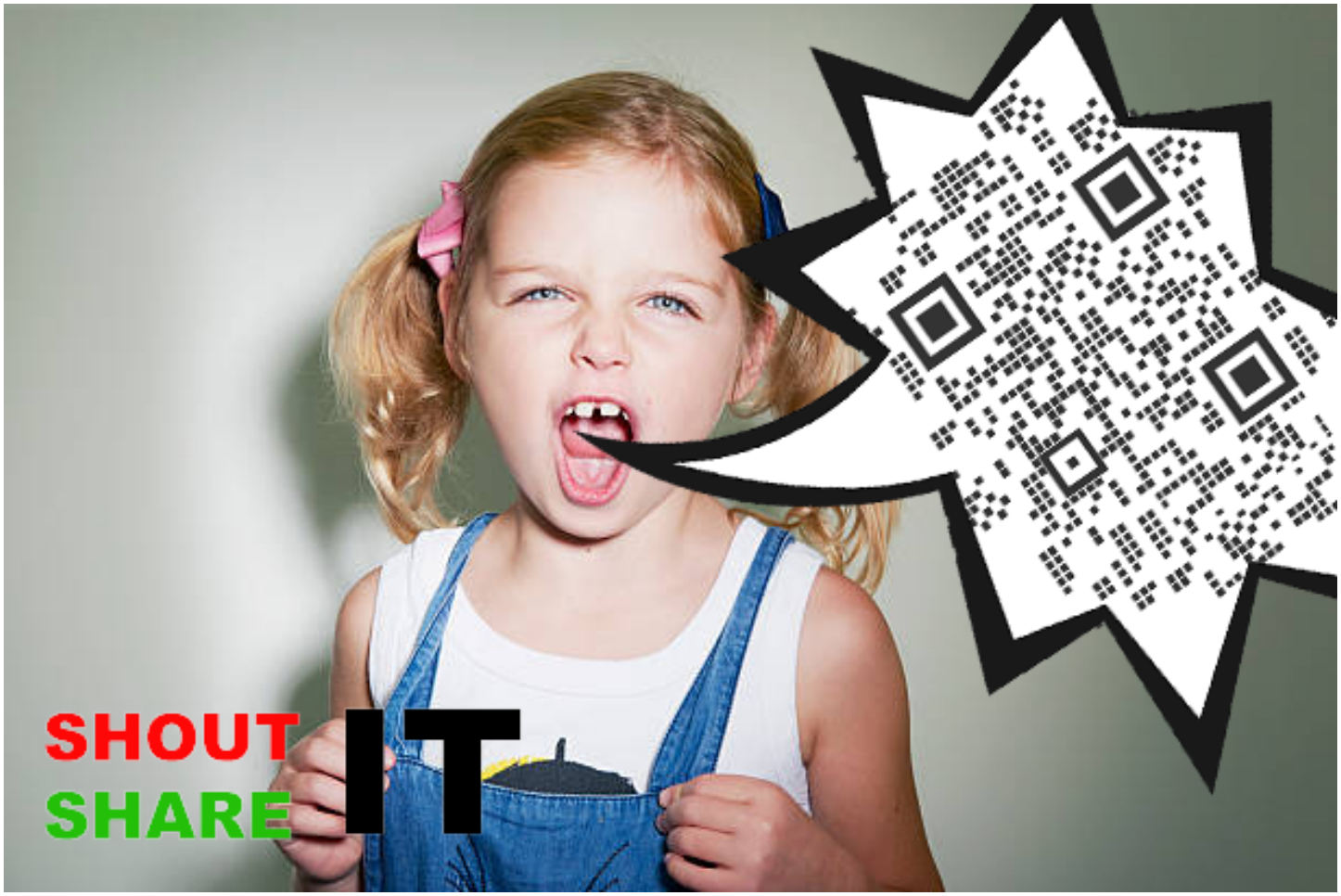
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UNITED STATES DEPARTMENT OF AGRICULTURE

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THE MEADOW DEATH CAMAS (ZYGADENUS VENENOSUS) AS A POISONOUS PLANT.

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IMPORTANCE OF STUDY OF ZYGADENUS VENENOSUS.

While there is considerable difference of opinion among systematic botanists as to the number of species of the death camas (Zygadenus) which should be recognized, they are fairly well agreed on the four species most likely to be encountered by stockmen using the western ranges. These four species are grassy death camas, *Z. gramineus;* foothill death camas, *Z. paniculatus;* mountain death camas, *Z. elegans;* and meadow death camas, *Z. venenosus.*

The general subject of death-camas poisoning, with special reference to *Z. gramineus,* wrongly identified at that time as *Z. venenosus,* was treated in Department Bulletin 125, United States Department of Agriculture. Department Bulletin 1012 gave the result of investigational work on *Z. paniculatus* and *Z. elegans.* During the summer of 1921 a special study of the true *Z. venenosus* was made.

While *Z. venenosus* is nominally the subject of many papers, there has been much confusion in the use of the name, and many of the publications under this name were evidently about other species. In the older publications it was much the fashion, because the plants were poisonous, to call the forms seen *venenosus* without attempting to discriminate between them. This has been particularly true of those publications which discussed the plants from the standpoint of their poisonous properties. It is safe to assume that in publications in regard to death camas in Montana, Wyoming, and Colorado the species referred to was not *Z. venenosus* but was in most cases *Z. gramineus.* So far as preceding experimental work is concerned, there are only two papers in which it can reasonably be assumed that this species was treated, viz, S. B. Nelson, 1906, and Fleming and coauthors, 1921.[1]

[1] See references to literature at end of bulletin.

While this species has been quite generally recognized as poisonous, very little has been definitely known of the actual effect of the plant on animals, except the fact that it produced sickness. The work reported in Bulletin 1012, which showed that *Z. paniculatus* and *Z. elegans* differ widely in their toxic properties, both from each other and from *Z. gramineus*, made it a matter of interest and importance to examine *Z. venenosus* in the same way.

DESCRIPTION AND DISTRIBUTION OF THE PLANT.[2]

Zygadenus venenosus is the so-called lobelia of the stockmen of Oregon and California, and might well be called the meadow death camas from its habitat.

The plant, shown in Plate I, is more slender and delicate than *Z. paniculatus*. The bulbs are oblong-ovate, about half an inch in diameter, and coated, the outer coat usually fibrous. The stems are 6 inches to 2 feet high. The leaves are linear, 4 to 12 inches long, one-sixth to one-fourth inch wide, striate, roughish, and often folded. The stem leaves are without sheaths, but the root leaves are sheathed. The raceme is simple, appearing flat-topped when young, later becoming elongated with membranaceous or foliaceous bracts, which are bristle pointed and acuminate. The pedicels are slender, one-fourth to 1 inch long, and erect in fruit. The flowers are polygamous and greenish white. The ovate to elliptical flower segments are free from the ovary and one-sixth to one-fourth inch long, obtuse or nearly so, with short claws and with glands extending slightly beyond the claws, the margin of the glands being irregular. The stamens are longer than the segments and slightly adhering to them. The capsules are one-third to one-half inch long, oblong-ovate. The seeds are numerous, brownish, angled, and somewhat margined.

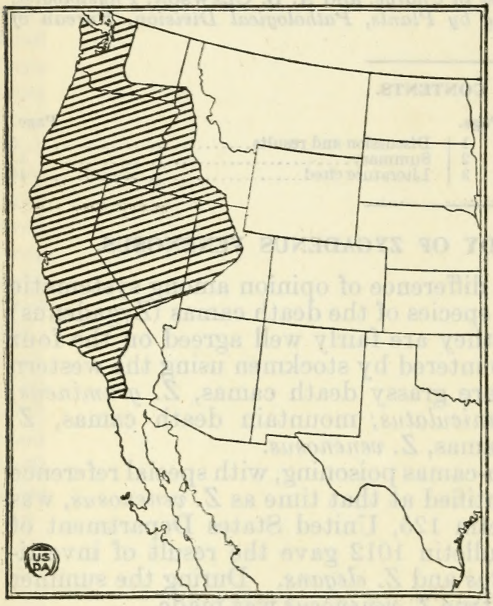

FIG. 1.—Distribution of *Zygadenus venenosus* in the United States.

The plant is known from British Columbia south to southern California and eastward to the Wasatch Mountains of northern Utah. It is abundant in Washington west of the Cascade Mountains, and is found in the valley of the Columbia River and of the Snake River into Idaho. It usually occurs in the higher altitudes, reaching 7,000 feet in the Wasatch Mountains, but is also found on the coast about Puget Sound.

Its natural habitat is springy meadows and stream banks in sand and gravel. Figure 1 shows its distribution in the United States.

[2] The description of *Zygadenus venenosus* and the statement of its distribution were prepared by W. W. Eggleston, of the Bureau of Plant Industry.

EXPERIMENTAL WORK.

During the season of 1921, 3 experimental feedings of the plant were made on cattle, 37 on sheep, and 3 on swine. Of these feedings, those on sheep are considered the most important, both because most of the recorded cases of Zygadenus poisoning are of sheep and because the extended experimental work on sheep with the other species of Zygadenus furnishes a fairly accurate standard for determining the comparative toxicity of the species.

A quantity of the typical plant was collected when in full bloom at Doyle, Calif., June 16 and 17, 1921, and the work here reported was done with that material at the experiment station near Salina, Utah. Table 1 gives a summarized statement of these experiments.

TABLE 1.—*Summary of feeding experiments with Zygadenus venenosus.*

Animal.		Date of feeding.	Method of feeding.	Part of plant fed.	Weight of plant.[1]	Result.	Remarks.
Designation.	Weight.						
Cattle:	*Pounds.*	1921.			*Pounds.*		
No. 903..	683	Sept. 14–16.	In hay..	Leaves, stems, and flowers.	1.0	Not sick...	Dry plant fed; estimated as green. Eaten rather slowly.
No. 900..	466	Sept. 19....	...do.....	.....do.....	.838	Sick.....	Dry plant fed; estimated as green.
No. 905..	440	.....do.....	...do.....	.....do.....	1.311	.....do.....	Do.
Sheep:							
No. 633..	82	July 1.....	Balling gun.	Leaves, stems, flowers, and some bulbs.	.623	.....do.....	Do.
No. 634..	86.5	July 2.....	...do.....	.....do.....	.372	Symptoms.	Do.
No. 637..	102	July 5.....	...do.....	.....do.....	.512	.....do.....	Do.
No. 642..	108.5	July 6.....	...do.....	.....do.....	.718	.....do.....	Do.
No. 643..	103.5	July 7.....	...do.....	.....do.....	.718	Not sick....	Do.
No. 645..	122.5	July 8.....	...do.....	.....do.....	.919	Sick.....	Do.
No. 646..	127	July 9.....	...do.....	.....do.....	.932	.....do.....	Do.
No. 649..	108.5	July 11.....	...do.....	.....do.....	.980	.....do.....	Do.
No. 603..	113.5	July 14.....	...do.....	.....do.....	1.047	Symptoms.	Do.
No. 615..	105	July 19.....	...do.....	.....do.....	1.102	Sick.....	Do.
No. 611..	146.5	July 22.....	...do.....	.....do.....	1.102	.....do.....	Do.
No. 624..	91	Aug. 1.....	...do.....	.....do.....	1.2	.....do.....	Do.
No. 627..	112.25	Aug. 4.....	...do.....	.....do.....	1.3	.....do.....	Do.
No. 637..	111.25	Aug. 10.....	...do.....	.....do.....	2	Death.....	Do.
No. 643..	114	Aug. 12.....	...do.....	.....do.....	1.496	Sick.....	Do.
No. 645..	128	Aug. 12–19.	In hay..	.....do.....	1.72	Symptoms.	Dry plant fed; estimated as green. Sick four different times.
No. 646..	132	Aug. 13–19.	.. do.....	.....do.....	1.72	Not sick...	Dry plant fed; estimated as green. Ate only a small part of it.
No. 642..	115.5	Aug. 14....	Balling gun.	.....do.....	1.6	Sick.....	Dry plant fed; estimated as green.
No. 541..	137.25	Aug. 23–25.	In hay..	Leaves, stems, and flowers.	1.8	Not sick....	Dry plant fed; estimated as green. Ate very little.
No. 612..	109.5	Aug. 29....	Balling gun.	Leaves, stems, flowers, and some bulbs.	1.7	Very sick..	Dry plant fed; estimated as green.
No. 617..	121	Sept. 5.....	...do.....	.....do.....	1.7	.....do.....	Do.
No. 639..	87	Sept. 10....	...do.....	.....do.....	1.8	.....do.....	Do.
No. 641..	112	Sept. 12....	...do.....	Bulbs.....	.5	Somewhat sick.	Do.
No. 651..	106.5	Sept. 13....	...do.....	Leaves, stems, flowers, and some bulbs.	.25	Not sick....	Do.
No. 652..	114.75	.....do.....	...do.....	Bulbs.....	.25	.....do.....	Do.
No. 645..	127.5	Sept. 14....	...do.....	Leaves, stems, flowers, and some bulbs.	.4	Symptoms.	Do.
No. 646..	128.5	.....do.....	...do.....	Bulbs.....	.4	Slightly sick.	Do.
No. 541..	137	Sept. 15....	...do.....	.....do.....	.3	Symptoms.	Do.

[1] Estimated as green plant per 100 pounds of animal.

TABLE 1.—*Summary of feeding experiments with Zygadenus venenosus.*

Animal.		Date of feeding.	Method of feeding.	Part of plant fed.	Weight of plant.	Results.	Remarks.
Designation.	Weight.						
Sheep—Con.	*Pounds.*	1921.			*Pounds.*		
No. 611..	157	Sept. 15.	Balling gun.	Leaves, stems, flowers, and some bulbs.	0.3	Not sick....	Dry plant fed; estimated as green.
No. 627..	117.5	Sept. 16....	...do.....	Flowers.....	.5	.....do.....	Do.
No. 653..	91.75	.....do.....	...do.....	Stems.....	.5	.....do.....	Do.
No. 613..	126.75	Sept. 19....	...do.....	Flowers.....	.75	Symptoms.	Do.
No. 614..	111.25	.....do.....	...do.....	Stems.....	.75	.....do.....	Do.
No. 582..	116.75	Sept. 21....	...do.....	Leaves.....	.5	.....do.....	Do.
No. 603..	114.5	.....do.....	...do.....	Flowers.....	.5	Not sick....	Do.
No. 620..	116	.....do.....	...do.....	Stems.....	.5	Symptoms.	Do.
No. 642..	112.5	.....do.....	...do.....	Bulbs.....	.5	Sick.....	Do.
Pigs:							
No. 23...	43	Sept. 24....	In bran.	.....do.....	.....	Vomited...	Dry plant fed; estimated as green. Pig ate very little of the mixture.
No. 22...	41	Sept. 26....	...do.....	.....do.....	.117	.....do.....	Do.
No. 23...	43	.....do.....	...do.....	.....do.....	.067	.....do.....	Do.

A TYPICAL SHEEP CASE.

Sheep 617 was a yearling ewe, weighing at the time of this experiment 121 pounds. It may be considered as a typical case of a "very sick" animal.

On September 5, between 2.02 and 2.16 p. m., she was given, by the balling gun, 1.7 pounds per 100 pounds of animal of leaves, stems, flowers, and some bulbs of *Zygadenus venenosus*. The temperature of the animal just before the feeding was 102.8° F. Immediately after the feeding a little of the material was vomited, the nausea perhaps being caused by mechanical irritation. The animal showed no further symptoms until 6.48 p. m., when she was noticed to be regurgitating. At 9 p. m. there was not only regurgitation but salivation. The temperature at this time was 101.2° F., the pulse 60.

At 7.47 a. m. September 6 the sheep was found lying down, and when compelled to get up, staggered as she walked and soon had to lie down. The temperature at this time was 101.1° F. and the pulse 120. At 8.59 a. m. the pulse was 116 and irregular, and the temperature was 100.4° F. The animal was still weak and grated her teeth. These symptoms continued during the forenoon, the animal being down most of the time, but still able to stand. At 3.33 p. m. she was strong enough to walk out of the corral to obtain water. During the rest of the afternoon and evening there was little change, the animal lying down most of the time and sometimes groaning with the expirations.

At 9.01 a. m., September 7 the condition of the animal was much the same as during the preceding day, but she was perhaps somewhat weaker. This condition continued with little change during the rest of the day. The animal was able to move about some, but was extremely weak. At 5.13 p. m. the temperature was 99.6° F.; respiration 80. This was the lowest temperature that was noticed during the sickness of the animal.

At 7.03 a. m. September 8 the temperature was 101.1° F.; pulse 76, strong and regular. The sheep was standing and grating her

teeth, but was very much better than on the preceding day. During the day the general condition of the animal improved rapidly.

At 8.45 a. m. September 9 the temperature was 103.4° F.; pulse 108, but somewhat irregular. The weakness had disappeared, and except for the slight irregularity of the pulse the animal was considered recovered.

DISCUSSION AND RESULTS.

SYMPTOMS OF POISONING.

The symptoms following the feeding of the plant to the experimental animals were carefully observed and are summarized below.

SYMPTOMS IN SHEEP.

Salivation.—Salivation, shown by "frothing at the mouth," occurred in 18 of the 28 cases in sheep that showed symptoms. Plate II, Figure 1, shows a salivating case, sheep 611.

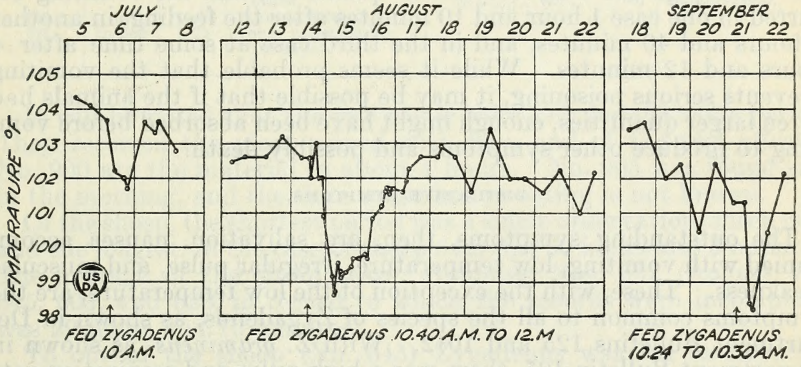

FIG. 2.—Temperature curve for sheep 642.

Nausea.—Thirteen of the sheep gave evidence of nausea, and in 11 animals this resulted in vomiting. The nausea was accompanied with frequent regurgitation and with grating of the teeth in 9 cases.

Weakness.—Sixteen of the animals exhibited muscular weakness shown especially in a staggering gait. In 6 animals this weakness was most pronounced in the hind legs. Sheep 617, while able to hold herself up, was down most of the time for a prolonged period. Sheep 639 was completely prostrated for 25½ hours and much of the time was in a condition of coma.

Temperature.—There was a distinct lowering of the temperature in 14 cases. Figure 2 gives the curve of temperature of sheep 642, showing the marked depression which occurred at the three different times it received the plant. It may be noted that this animal was severely poisoned in August and September, while in July it was only slightly affected. The curve of July shows a distinct depression, but not so marked as at the other times.

Pulse.—It was noticed that the pulse was weak at some stages of the illness in 8 cases. An irregular or intermittent pulse was noted in 14 animals.

Respiration.—The rate of respiration varied, but had no characteristic peculiarities. In one animal it was labored at one period of the illness.

SYMPTOMS IN CATTLE.

As only two head of cattle were made sick, no final conclusions can be drawn as to the effect on these animals as compared with sheep.

Neither of these animals was salivated or nauseated. Both exhibited weakness, one of them being unable to rise. Both had a lowered temperature and one labored breathing.

Plate II, Figure 2, shows cattle 900 when this animal was exhibiting extreme weakness.

SYMPTOMS IN SWINE.

The only symptom exhibited by swine was vomiting. In this connection it is a matter of interest that many authors state that swine are not poisoned by Zygadenus. If this is true, it may be inferred that these animals do not suffer from the plant because its emetic action disposes of the material so completely that no further symptoms appear. These experiments, however, do not positively confirm this, for these pigs ate only very small quantities, and the vomiting occurred in one case 1 hour and 10 minutes after the feeding, in another 2 hours and 40 minutes, and in the third case at some time after 4 hours and 12 minutes. While it seems probable that the vomiting prevents serious poisoning, it may be possible that if the animals had eaten larger quantities, enough might have been absorbed before vomiting to produce other symptoms and possibly death.

DISTINCTIVE SYMPTOMS.

The outstanding symptoms, then, are salivation, nausea accompanied with vomiting, low temperature, irregular pulse, and muscular weakness. These, with the exception of the low temperature, are the symptoms common to all the species of Zygadenus, as shown in Department Bulletins 125 and 1012. With *Z. gramineus*, as shown in Department Bulletin 125, there was a high pulse and respiration rate in very sick animals. This was not observed in the *Z. elegans* and *Z. venenosus* cases and was observed in only one of the *Z. paniculatus* cases. This is explained by the fact that *Z. gramineus* produces much more acute and serious cases of poisoning than the other species, although the toxic doses of *Z. gramineus* and *Z. venenosus* are practically the same.

DURATION OF SYMPTOMS.

Table 2 shows the time between the first and last symptoms noted. As in the similar tables in Department Bulletin 1012, doubtless the actual time would be somewhat longer, as, owing to the fact that observations were not made continuously, sickness in many cases was present before the first observation was made and continued after the time of the last note.

TABLE 2.—*Time elapsing between first and last noted symptoms.*

Animal.	Method of feeding.	Dosage.	Time sick.	Animal.	Method of feeding.	Dosage.	Time sick.
		Lbs. per cwt.		Sheep No.—Con.		*Lbs. per cwt.*	
Cattle No.:				642....	Balling gun.	1.6	90 hours 5 minutes.
900....	In hay.	0.838	50 hours.				
905....	...do...	1.311	50 hours.	612....	...do...	1.7	44 hours 2 minutes.
Sheep No.:				617....	...do...	1.7	60 hours 17 minutes.
633....	Balling gun.	.623	13 hours 5 minutes.	639....	...do...	1.8	88 hours 56 minutes.
				641....	...do...	.5	27 hours 45 minutes.
634....	...do...	.372	52 minutes.	645....	...do...	.4	18 hours 50 minutes.
637....	...do...	.512	2 hours 15 minutes.	646....	...do...	.4	24 hours 2 minutes.
642....	...do...	.718	23 hours 35 minutes.	541....	...do...	.3	2 hours 15 minutes.
645....	...do...	.919	25 hours 53 minutes.	613....	...do...	.75	48 minutes.
646....	...do...	.932	36 hours 50 minutes.	614....	...do...	.75	2 hours 9 minutes.
649....	...do...	.980	42 hours 57 minutes.	582....	...do...	.5	3 hours 11 minutes.
603....	...do...	1.047	One observation.	620....	...do...	.5	2 observations.
615....	...do...	1.102	42 hours 23 minutes.	642....	...do...	.5	21 hours 33 minutes.
611....	...do...	1.102	26 hours 12 minutes.	Pig No.:			
624....	...do...	1.2	66 hours 10 minutes.	23.....	In bran	(?)	3 hours 55 minutes.
627....	...do...	1.3	48 hours 40 minutes.	22.....	...do...	.117	3 hours 50 minutes.
637....	...do...	2.0	One observation; death.	23.....	...do...	.067	1 observation.
643....	...do...	1.496	18 hours 57 minutes.				
645....	In hay.	1.72	4 observations, different days.				

It will be noted that the two cattle were sick for the same period. They received the plant mixed with hay, and of the two affected No. 900 ate the material in about 4 hours. No. 905 was found sick in the morning, and the time consumed in eating is not known.

Of the sheep, the shortest period was a single observation, sheep 603; and the longest, in the case of sheep 642, was 90 hours and 5 minutes. The average of the sheep cases, excluding Nos. 637 (August 10), 645, 603, and 620, in regard to which the records were incomplete, was 29 hours and 16 minutes.

To one of the sheep (No. 645) Zygadenus was fed in hay, the feeding being continued for 8 days, and during this period the sheep was sick four times. All the other sheep were fed by the balling gun.

Of the 3 pigs, one was sick during the night when not under constant observation. In the other two cases, the duration of illness was approximately the same with an average of 3 hours and 52 minutes.

To the pigs chopped bulbs were given, mixed with bran. Pig 23, September 24, ate only a couple of mouthfuls. Pig 22 ate 0.117 pound of the plant in 2 minutes. Pig 23, September 26, ate 0.067 pound of the plant in 1 minute. In each case the pig vomited, emptying the stomach quite thoroughly, and had no further symptoms.

COMPARISON OF DURATION OF SYMPTOMS FROM DIFFERENT SPECIES OF ZYGADENUS.

In Table 3 are included the maximum, minimum, and average duration of illness in experimental sheep which were either force-fed or drenched. In this table the deaths are included as well as recoveries, inasmuch as a comparison of figures did not seem to indicate that the duration of illness was shortened by a fatal issue.

TABLE 3.—*Duration of illness in cases of sheep poisoned by species of zygadenus.*

Species of Zygadenus.	Maximum.	Minimum.	Average.
Z. gramineus	79 hours 20 minutes (died); 68 hours 20 minutes (recovered).	1 observation [1]	12 hours 1 minute.
Z. paniculatus	96 hours	do	36 hours 2 minutes.
Z. elegans	20 hours 6 minutes	do	5 hours 19 minutes.
Z. venenosus	90 hours 5 minutes	do	29 hours 16 minutes.

[1] Duration of time not recorded.

It will be noticed that, exclusive of those cases in which there was only a single observation, the shortest average time during which the symptoms persisted was in the case of animals poisoned by *Zygadenus elegans* and the longest time in those poisoned by *Z. paniculatus*. Possibly it might be assumed that the duration of illness was correlated with the greater or less toxicity of the plant. This does not seem to hold, however, inasmuch as the average duration in the *Z. venenosus* cases was more than twice that of the *Z. gramineus* cases, while the longest duration of illness was in those sheep poisoned by *Z. paniculatus*, although this is not so toxic as either *Z. venenosus* or *Z. gramineus*.

TIME ELAPSED BETWEEN FEEDING OF PLANT AND DEVELOPMENT OF SYMPTOMS.

The cattle received the plant in hay and the feeding was extended over a considerable period of time, so that it is impossible to tell with any accuracy the time necessary to develop symptoms. In both cases the eating covered about 2 hours and the symptoms were noted 2 hours after the feeding was completed.

In the case of the pigs, while they were fed with bran, they ate the material immediately, so that they could well be compared with sheep fed by the balling gun. In the second feeding of pig 23 the symptoms were noted in the morning, but it was evident from the vomited material that it had been sick in the night; the time when these symptoms first appeared was not known. Of the other two cases the symptoms appeared in one pig in 1 hour and 10 minutes, and in the other in 2 hours and 38 minutes. The average of the two was 1 hour and 54 minutes.

Table 4 shows the period of development of symptoms in sheep, including only those fed by balling gun, and of these excluding Nos. 634, 637, 646, and 603, as these animals became sick in the night at a time when no observations were made.

TABLE 4.—*Time elapsed between feeding of plant and development of symptoms in sheep fed by balling gun.*

Sheep No.	Date.	Time to symptoms.	Sheep No.	Date.	Time to symptoms.
633	July 1	8 hours 1 minute.	612	Aug. 29	1 hour 24 minutes.
642	July 6	6 hours 29 minutes.	617	Sept. 5	4 hours 32 minutes.
645	July 8	1 hour 58 minutes.	639	Sept. 10	1 hour 8 minutes.
649	July 11	2 hours 13 minutes.	641	Sept. 12	1 hour 34 minutes.
615	July 19	1 hour 2 minutes.	645	Sept. 14	2 hours 23 minutes.
611	July 22	2 hours 22 minutes.	646	do	4 hours 45 minutes.
624	Aug. 1	1 hour 35 minutes.	541	Sept. 15	3 hours 19 minutes.
627	Aug. 4	1 hour 58 minutes.	613	Sept. 19	2 hours 35 minutes.
637	Aug. 10	1 hour 40 minutes; death.	614	do	2 hours 43 minutes.
			582	Sept. 21	2 hours 14 minutes.
643	Aug. 12	1 hour 47 minutes.	620	do	9 hours 40 minutes.
642	Aug. 14	1 hour 5 minutes.	642	do	44 minutes.

ZYGADENUS VENENOSUS, MEADOW DEATH CAMAS, SHOWING THE PLANT IN BLOOM.

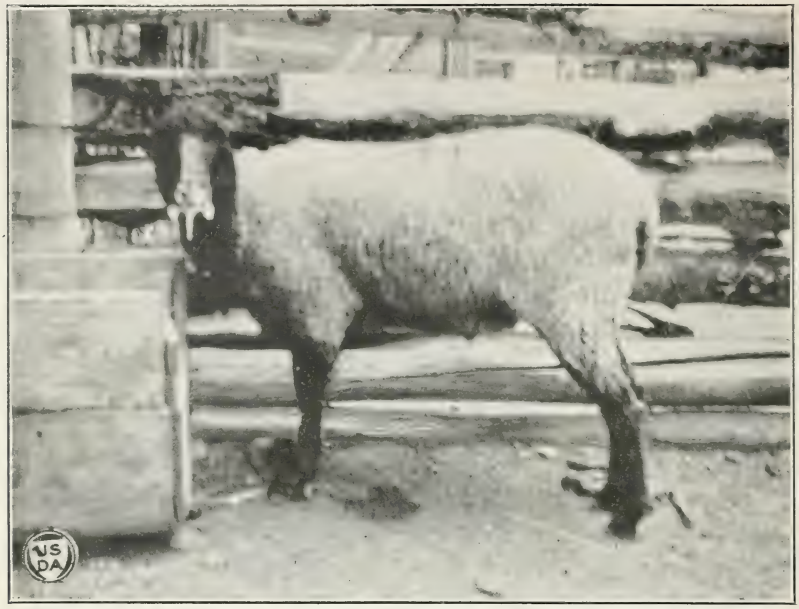

FIG. 1.—SHEEP 611, WHEN STRONGLY SALIVATED BY ZYGADENUS VENENOSUS.

FIG. 2.—CATTLE 900, POISONED BY ZYGADENUS VENENOSUS, AND SO WEAK AS TO BE UNABLE TO STAND.

The longest period was 9 hours and 40 minutes, and the shortest 44 minutes, with an average of all cases of 2 hours and 55 minutes.

COMPARISON OF SPECIES IN REGARD TO TIME BEFORE DEVELOPMENT OF SYMPTOMS.

Table 5 presents a comparison of the different species of Zygadenus in regard to the time elapsed between the feeding of the plant to sheep and the development of symptoms.

TABLE 5.—*Minimum, maximum, and average time elapsed between feeding of Zygadenus species to sheep and development of symptoms.*

Species.	Maximum.	Minimum.	Average.
Z. gramineus	7 hours 30 minutes	5 minutes	1 hour 22½ minutes.
Z. paniculatus	8 hours 40 minutes	55 minutes	3 hours 14 minutes.
Z. elegans	7 hours	Immediately	1 hour 53 minutes.
Z. venenosus	9 hours 40 minutes	44 minutes	2 hours 25 minutes.

So far as this table is concerned, it does not appear that there is any marked difference between the time of development of symptoms in the different species of Zygadenus examined. It will be noted that the maximum time is practically the same. While in the average figures it appears that a somewhat longer time elapsed in the case of *Zygadenus paniculatus*, it is not thought that any significance should be attached to these figures.

In the three classes of animals used in the *Zygadenus venenosus* experiments—cattle, sheep, and pigs—the latent period is practically the same.

AUTOPSY FINDINGS.

There was opportunity for an autopsy on only one animal, sheep 637. This animal was given *Zygadenus venenosus* by balling gun at 11 a. m. and was found dead at 12.40 p. m. It had died between 11.25 a. m. and 12.40 p. m. It was lying on the right side, much bloated, and there was evidence in the corral that it had vomited profusely. The autopsy was commenced at 1.40 p. m.

The left ventricle was contracted and the right expanded. In the trachea there was some froth, but it contained none of the stomach contents. There was some congestion in the lungs. The stomachs were normal, except that the first stomach had an unusual quantity of gas. There were areas of congestion in the ileum. In other respects the alimentary canal was normal, except that the colon was distended with gas. The thymus was filled with hemorrhagic spots. All other organs were normal.

MICROSCOPIC CHANGES IN TISSUES.

On microscopic examination, capillary congestion was well marked in several of the organs, principally in the lungs, spleen, pancreas, thymus, and thyroids. In the medullary portion of many lobules of the thymus there were hemorrhagic areas, probably due to the diapedesis of erythrocytes.

In most of the tissues examined changes in the parenchyma were slight. The kidneys, however, were a marked exception. There was a pronounced acute parenchymatous nephritis which particularly

affected the epithelium of the convoluted tubules, the ascending limb of Henle, and the capsule of Bowman.

The liver was much less affected. There was a mild, cloudy swelling of the hepatic cells, with beginning granular degeneration in the cytoplasm bordering on the capillaries. The bile ducts were usually catarrhal and sometimes an infiltration of round cells had occurred. The condition of the bile ducts was probably not caused by the Zygadenus.

The principal effect on the lungs was a mild capillary congestion. In the more congested areas there was a considerable quantity of yellowish, granular pigment, such as is derived from the degeneration of red blood corpuscles. This was largely lying free in the tissue spaces. There was also a mild catarrhal condition of the small bronchial tubes and the bronchioles.

The tissues most affected were the epithelial cells of the convoluted tubules, ascending limb of Henle, and capsule of Bowman in the kidneys, and to a less degree the hepatic cells and bile duct epithelium of the liver.

As tissues from only a single animal were studied, too great importance should not be attached to the findings. The conditions, however, seem to suggest that the toxin was mainly excreted by the kidneys, and that the liver played a less important part in eliminating the poison.

The results of microscopic studies on the tissues of a number of animals fatally poisoned by other species of Zygadenus correspond to the findings recorded for this case.

TOXICITY OF PLANT AND SUSCEPTIBILITY OF ANIMALS.

TOXIC AND LETHAL DOSAGE.

Sheep.—An examination of Table 1 shows that the minimum toxic dose of the force-fed sheep was 0.3 pound per 100 pounds of animal, in the case of sheep 541. This animal showed only symptoms. It should be noted that sheep 603 exhibited only symptoms on 1.047 pounds per 100 pounds of animal, a quantity more than three times as great as that received by sheep 541. The severity of the effect of the plant was indicated in the table by the terms "symptoms," "sick," and "very sick." Of the "sick" sheep the minimum dose was that of sheep 642, namely, 0.5 pound; the same sheep in another experiment received 1.6 pounds with a similar effect. The minimum dose making the animal "very sick" was 1.7 pounds in sheep 617 and the maximum 1.8 pounds in sheep 639.

It will thus be seen that there is considerable latitude in the toxic dosage, for while a sheep was poisoned on 0.3 pound, sheep 643 on July 7 received 0.718 pound with no effect.

The only animal killed was sheep 637, which received 2 pounds per 100 pounds of animal. This is probably very close to the minimum lethal dose, for of the other force-fed cases not resulting in death, sheep 642 received 1.6 pounds; sheep 612, 1.7 pounds; sheep 617, 1.7 pounds; and sheep 639, 1.8 pounds. It may be noted that Fleming and coauthors (1921, p. 17) report a case of death of a sheep on 2 pounds of this plant.

Cattle.—Only 2 head of cattle were poisoned, and the minimum dose was 0.838 pound per 100 pounds of animal, in No. 900, while No. 903

ate 1 pound with no effect. It would appear that 0.838 pound per 100 pounds is not far from the minimum dose under the conditions of the experiments. These figures are not comparable with those for sheep, as the cattle did not eat the plant immediately, and the dosage would consequently be likely to be greater. Fleming and coauthors (1921, p. 21) report poisoning a calf on 0.453 pound per hundredweight of animal. It seems probable that this result indicates more nearly the minimum dose than do those of this bulletin, for it was shown in Department Bulletin 1012 that *Zygadenus paniculatus* was probably more poisonous to cattle than to sheep, and it would be assumed that the same thing would be true of *Z. venenosus*.

Swine.—The minimum dose affecting pigs was 0.067 pound per 100 pounds of animal.

SUSCEPTIBILITY OF DIFFERENT ANIMALS.

These experiments have shown the effect of the plant on cattle, sheep, and swine. No experiments were made with horses, but there is abundant evidence of horses being made sick, sometimes with fatal results. Under range conditions neither cattle nor horses ordinarily eat enough of the plant to do any harm, but the loss of sheep is very large. The common method of handling sheep in the West, by which they are frequently close herded over the grazing areas so that they eat most of the vegetation, results in their eating more of poisonous plants.

COMPARATIVE TOXICITY OF PARTS OF PLANT.

In most of the experimental work with *Zygadenus venenosus* the whole plant was used, including leaves, stems, flowers, and some bulbs, and 18 sheep were poisoned in this way. To 1 sheep flowers were fed, to 2 stems, and 4 received bulbs. All these animals were fed in the same way, by the balling gun. The minimum effective doses were as follows:

	Lb. per cwt.
Leaves, stems, flowers, and some bulbs	0. 372
Flowers	. 75
Stems	. 5
Bulbs	. 3
Leaves	. 5

Because of the small number of cases in which flowers, stems, leaves, or bulbs were used separately, anything like exact inferences in regard to the comparative toxicity of the parts can hardly be drawn. It would seem, however, that the bulbs are somewhat more toxic than the other parts of the plant.

COMPARATIVE TOXICITY OF SPECIES OF ZYGADENUS.

Table 6 shows the minimum toxic dosage of *Zygadenus gramineus, Z. paniculatus, Z. elegans,* and *Z. venenosus,* expressed in pounds per hundredweight of animal. All these cases were either force-fed or drenched, except in the case of the seeds of *Z. gramineus,* which were fed.

TABLE 6.—*Comparative toxicity of species of Zygadenus.*

[Minimum toxic dosage in pounds of plant per 100 pounds of animal.]

Parts of plant.	Z. gramineus.	Z. paniculatus.	Z. elegans.	Z. venenosus.
Leaves, stems, and young fruit	0.757	1.505	.....	.....
Leaves and stems	.33	1.984	3.748	.....
Fruit heads	.161	.62	[1] 2.437	.....
Seeds	.093	.07	1.807	.....
Leaves, stems, and buds	.495	1.096	1.97	.....
Leaves, stems, and flowers	.....	1.323	2.939	.....
Leaves, stems, flowers, and buds	.495	.....	.....	.....
Leaves, stems, flowers, and bulbs	.....	.....	2.373	0.372
Bulbs	[2] .595	.....	3.0	.3

[1] No effect. [2] One case.

From the experimental work on toxicity and the comparisons made in Table 6, it appears that *Zygadenus gramineus* and *Z. venenosus* are equally toxic and that these species are three times as toxic as *Z. paniculatus* and seven times as toxic as *Z. elegans*.

COMPARATIVE LETHAL DOSE OF SPECIES OF ZYGADENUS.

The minimum lethal doses of the four species of Zygadenus with which experiments have been made, expressed in pounds per 100 pounds of animal, are as follows:

Zygadenus gramineus	0.544
Zygadenus paniculatus	2.5
Zygadenus elegans	6.153
Zygadenus venenosus	2.0

So far as these figures go, it appears that the lethal doses of *Zygadenus paniculatus* and *Z. venenosus* are, respectively, about 5 and 4 times that of *Z. gramineus*, while that of *Z. elegans* is more than 11 times that of *Z. gramineus*.

The ratio between the toxic and lethal doses of the four species is a matter of considerable interest. This ratio of minimum toxic to minimum lethal dosage is as follows:

Zygadenus gramineus	About 4 to 5.
Zygadenus paniculatus	About 1 to 2.
Zydadenus elegans	About 1 to 3.
Zygadenus venenosus	About 1 to 5½.

That is, while the ratio of toxic to lethal doses does not differ widely in *Zygadenus gramineus*, *Z. paniculatus*, and *Z. elegans*, in *Z. venenosus*, which has practically the same toxic dose as *Z. gramineus*, the lethal dose is three and one-half times as great. The practical bearing of this ratio is that while *Z. gramineus* and *Z. venenosus* are about equally dangerous so far as making sheep sick is concerned, the chances of death are much greater in cases poisoned by *Z. gramineus*. As the actual minimum lethal dose is about the same in *Z. paniculatus* and *Z. venenosus*, it would appear that the chances of a fatal issue are about equally probable in these two species.

SUMMARY.

Zygadenus venenosus (meadow death camas) is the species of death camas that is especially characteristic of the States bordering on the Pacific Ocean.

The plant affects sheep more than any other class of animals. Many horses, however, are poisoned and some are killed. While it is poisonous to cattle, few are injured under range conditions. Swine are probably not harmed, because they promptly expel the plant by vomiting.

Z. venenosus is about equally toxic with grassy death camas (*Z. gramineus*), and these plants are three times as toxic as the Great Basin foothill death camas (*Z. paniculatus*) and seven times as toxic as the mountain death camas (*Z. elegans*).

While *Z. venenosus* and *Z. gramineus* have about the same toxic dose, the lethal dose of *Z. venenosus* is much greater. It follows that in the production of deaths *Z. gramineus* is the more dangerous. *Z. venenosus* and *Z. paniculatus* are about equally dangerous, so far as the production of deaths is concerned.

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